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C. Georges Bank Yellowtail Flounder

by

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C. Georges Bank Yellowtail Flounder

1.0 Background

The Georges Bank yellowtail flounder stock is jointly managed by the US and Canada through the Transboundary Management Guidance Committee (TMGC). Stock assessments are conducted annually by the Transboundary Resources Assessment Committee (TRAC). A benchmark assessment most was recently completed in 2005 (TRAC 2005) focused on the issue of the strong retrospective pattern. Based on this benchmark assessment and subsequent assessments (Legault et al. 2006, Legault et al. 2007), the so-called "Major Change" model has been utilized to provide stock management advice. This model splits the survey time series between 1994 and 1995 to reduce the retrospective pattern. This split is most appropriately thought of as "aliasing of an unknown mechanism that produces a better fitting model" (Legault et al. 2007). Although the TMGC does not have explicit biomass reference points, these were calculated previously and have been used in US management decisions (NEFSC 2002a). Based on the current biological reference points, the stock is currently overfished and overfishing is occurring. This report updates the 1994-2006 US catch to reflect the Groundfish Assessment Review Meeting (GARM) Data Meeting recommendations (GARM 2007), conducts both virtual population analysis models recommended in the benchmark assessment, and provides a range of biological reference points for this stock.

2.0 Assessment Data

<u>2.1 US Landings</u>

U.S. landings of yellowtail flounder from Georges Bank during 1994-2006 were derived from the new trip-based allocation described in the GARM data meeting (GARM 2007, Table C1, Figure C1). Changes to previous estimates were minimal and uncertainty in the landings due to the random component of the allocation was insignificant (Legault et al. 2008). US landings have been limited by quotas in recent years. Landings at age and mean weight at age are determined by port sampling of small, medium, large, and unclassified market categories and pooled age-length keys by half year. Sampling intensity has increased in recent years (Table C2) resulting in lower variability in landings at age estimates (Table C3).

<u>2.2 US Discards</u>

US discarded catch for years 1994-2006 was estimated using the Standardized Bycatch Reporting Methodolgy recommended in the GARM data meeting (GARM 2007). Observed ratios of discards of yellowtail flounder to kept of all species for large mesh otter trawl, small mesh otter trawl, and scallop dredge were applied to the total landings by these gears by half-year. Uncertainty in the discard estimates was estimated based on the SBRM approach detailed in the GARM data meeting (GARM 2007, Table C4). US discards were approximately 11% of the US catch in years 1994-2006 (Table C1; Figure C1). Discards at age and associated mean weights at age were estimated from sea sampled lengths and pooled observer and survey age-length keys.

2.3 Canadian Landings
Canadian landings since 2004 have been well below previous levels and the allowed quota for that fishery (Table C1; Figure C1). Since 2003, scale samples from Canadian landings were aged by the US readers and these age-length keys used directly for these landings. Previously, US age-length keys had been applied to Canadian length frequency distributions.

2.4 Canadian Discards
During the 2005 benchmark assessment, yellowtail flounder discards from the Canadian scallop fleet were estimated for the entire time series and used in the stock assessment for the first time (Stone and Legault 2005). Inclusion of this catch did not cause a large change in the assessment results because the magnitude is relatively constant throughout the time series used in the assessment, 1973 onward (Table C1; Figure C1). Discards at length were estimated from ogives of relative selectivity compared to research survey catches at length and converted to ages using age-length keys from US and Canada commercial landings and observers by quarter.

2.5 Total Catch at Age
Total catch at age was formed by adding the US landings, US discards, Canadian landings, and Canadian discards (Table C5). Average weight at age was computed as the catch weighted average of the weights at age from these four sources (Table C6).

2.6 Research Vessel Survey Indices
Survey abundance and biomass indices are reported in Table C7. Estimates from research vessel surveys are from valid tows on Georges Bank (NEFSC offshore strata 13-21; Canadian strata 5Z1-5Z4; NEFSC scallop strata 54, 55, 58-72, 74) standardized according to net, vessel, and door changes. The three surveys of biomass show a similar pattern of rapid increase from lows in the early to mid 1990s to highs in the early 2000s followed by a decline in the most recent years (Figure C2).

3.0 Assessment Results

The 2005 benchmark assessment could not select a single formulation for Georges Bank yellowtail flounder VPA stock assessment. Instead, the previously used “Base Case VPA” (same formulation as GARM1, NEFSC 2002b and GARM2, Mayo and Terceiro 2005) was used along with a “Major Change VPA” which extended the ages from 6+ to 12, split the survey time series in 1995, and allowed for power functions relating survey abundance at age to model estimates. Assessments since the benchmark have modified the “Major Change” model to only differ from the Base Case by splitting the survey series between 1994 and 1995. Since these two formulations were thought to bracket the possible status of the stock, even though the only the Major Change model has been used for management advice in recent years, both are updated with the new 1994-2006 US landings and discards. Results are not noticeably different from the 2007 TRAC assessment with the Base Case VPA exhibiting a strong retrospective pattern (Figure C3) while the Major Change VPA does not (Figure C4). The stock recruitment plots for the two models were quite similar for most years, with differences occurring in only the most recent years (Figure C5).

Hindcast recruitment estimates were derived for both models by regressing the estimated numbers of recruits from the stock assessments on the NEFSC Fall survey index at age 1 (Figures C6-C7). Combining the hindcast and stock assessment recruitments produced geometric means for the two models for the highest 14 and 10 values of 70 and 89 million fish for the Base Case model and 64 and 80 million fish for the Major Change model.

4.0 Biological Reference Points

4.1 Current Biological Reference Points

Proxies for biological reference points were derived from yield and SSB per recruit analyses and the assumption of constant recruitment (NEFSC 2002a). Long-term average recruitment was estimated to be 53.8 million at age-1.

MSY = 12,900 mt
SSBmsy = 58,800 mt.
Fmsy = 0.25 fully recruited (derived from F40%)

4.2 Updated Biological Reference Points

Both parametric and empirical approaches to estimating biological reference points were utilized for the Base Case and Major Change models.

The parametric approach assumed: a Beverton and Holt stock recruitment relationship; average of the most recent five years for fishery selectivity, maturity (assumed constant over all years), and weight at age; natural mortality of 0.2 for all ages; and either no prior for unfished recruitment or else a prior on unfished recruitment from the top 14 or 10 years including hindcast estimates. The program SRFIT (NOAA Fisheries Toolbox) was used to fit the B-H curve and estimate Fmsy. The stock recruitment relationship and biological and fishery characteristics were then entered in AgePro (NOAA Fisheries Toolbox) for stochastic projections of 50 years of fishing at Fmsy, with median values for spawning stock biomass and yield assumed to be the SSBmsy and MSY values (see Legault 2008). The Base Case model had consistently lower Fmsy values than the Major Change model (Table C8). Forcing higher unfished recruitment through the use of a prior produced lower Fmsy and higher SSBmsy and MSY for both the Base Case and Major Change models (Table C8).

The empirical approach assumed: F40%SPR (the fishing mortality rate that reduces spawning stock biomass per recruit to 40% of the unfished level in equilibrium) is an appropriate proxy for Fmsy; the same biological and fishery characteristics as the parametric case (see above); and three different series of recruitment. The three series were formed from 1) the stock assessment estimates for years 1973-2006, 2) the top 14 values when the stock assessment series and the hindcast values were combined (14 was an arbitrary selection to include both “typical” high values and very high values), and 3) the top 10 values from the combined series of case 2 (again an arbitrary selection designed to produce higher recruitments). The program AgePro (NOAA Fisheries Toolbox) was used to estimate SSBmsy and MSY proxies using the cumulative distribution option for input recruitment. The F40%SPR values were nearly identical for the Base Case and Major Change models, while the SSBmsy and MSY proxies increased substantially with higher recruitment, as expected (Table C9).

Although the range of values for the Fmsy and SSBmsy reference points was quite high from the twelve cases, the status determination did not change much (Figure C8). Since the Base Case model exhibits a strong retrospective, any projections for this assessment relative to the reference point would need to incorporate some adjustment to account for the retrospective pattern (see Legault and Terceiro 2008). These adjustments would decrease the difference between the Base Case and Major Change models in terms of management advice.

The parametric Fmsy values are all much greater than the F40%SPR values used in the empirical approach, due to the high steepness associated with the stock recruitment curves (range 0.79-0.86 over the six models). However, in the empirical approach, the recruitment series are either low relative to hindcast values (1973-2006), or else employ arbitrary cut-offs for the predicted recruitment distribution under Fmsy conditions (top 14 and top 10). One way to balance the two approaches is to use a stock recruitment relationship to define future recruitment, but base Fmsy on F40%SPR instead of the calculated Fmsy value (Table C10).

Given the two stock assessments and fifteen reference point calculations, and taking into account the pros and cons of each combination, the ranges for biological reference points recommended for Georges Bank yellowtail flounder are

Model	R prior	Fmsy	SSBmsy	MSY
Major Change	80	0.254	97.0	21.0
Major Change	64	0.365	58.0	17.5

5.0 References

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Table C.1 Landings, discards, total catch (metric tons), and proportion of total catch which is discards for Georges Bank yellowtail flounder.

Year	US Landings	US Discards	Canada Landings	Canada Discards	Other Landings	Total Catch	% discards
1935	300	100	0	0	0	400	25%
1936	300	100	0	0	0	400	25%
1937	300	100	0	0	0	400	25%
1938	300	100	0	0	0	400	25%
1939	375	125	0	0	0	500	25%
1940	600	200	0	0	0	800	25%
1941	900	300	0	0	0	1200	25%
1942	1575	525	0	0	0	2100	25%
1943	1275	425	0	0	0	1700	25%
1944	1725	575	0	0	0	2300	25%
1945	1425	475	0	0	0	1900	25%
1946	900	300	0	0	0	1200	25%
1947	2325	775	0	0	0	3100	25%
1948	5775	1925	0	0	0	7700	25%
1949	7350	2450	0	0	0	9800	25%
1950	3975	1325	0	0	0	5300	25%
1951	4350	1450	0	0	0	5800	25%
1952	3750	1250	0	0	0	5000	25%
1953	2925	975	0	0	0	3900	25%
1954	2925	975	0	0	0	3900	25%
1955	2925	975	0	0	0	3900	25%
1956	1650	550	0	0	0	2200	25%
1957	2325	775	0	0	0	3100	25%
1958	4575	1525	0	0	0	6100	25%
1959	4125	1375	0	0	0	5500	25%
1960	4425	1475	0	0	0	5900	25%
1961	4275	1425	0	0	0	5700	25%
1962	5775	1925	0	0	0	7700	25%
1963	10990	5600	0	0	100	16690	34%
1964	14914	4900	0	0	0	19814	25%
1965	14248	4400	0	0	800	19448	23%
1966	11341	2100	0	0	300	13741	15%
1967	8407	5500	0	0	1400	15307	36%
1968	12799	3600	122	0	1800	18321	20%
1969	15944	2600	327	0	2400	21271	12%
1970	15506	5533	71	0	300	21410	26%
1971	11878	3127	105	0	500	15610	20%
1972	14157	1159	8	515	2200	18039	9%
1973	15899	364	12	378	300	16953	4%
1974	14607	980	5	619	1000	17211	9%
1975	13205	2715	8	722	100	16750	21%
1976	11336	3021	12	619	0	14988	24%
1977	9444	567	44	584	0	10639	11%
1978	4519	1669	69	687	0	6944	34%
1979	5475	720	19	722	0	6935	21%
1980	6481	382	92	584	0	7539	13%
1981	6182	95	15	687	0	6979	11%
1982	10621	1376	22	502	0	12520	15%
1983	11350	72	106	460	0	11989	4%
1984	5763	28	8	481	0	6280	8%
1985	2477	43	25	722	0	3267	23%
1986	3041	19	57	357	0	3474	11%
1987	2742	233	69	536	0	3580	21%
1988	1866	252	56	584	0	2759	30%
1989	1134	73	40	536	0	1783	34%
1990	2751	818	25	495	0	4089	32%
1991	1784	246	81	454	0	2564	27%
1992	2859	1873	65	502	0	5299	45%
1993	2089	1089	682	440	0	4300	36%
1994	1431	158	2139	440	0	4167	14%
1995	360	38	464	268	0	1130	27%
1996	743	71	472	388	0	1675	27%
1997	888	58	810	438	0	2194	23%
1998	1619	116	1175	708	0	3619	23%
1999	1818	484	1971	597	0	4870	22%
2000	3373	408	2859	415	0	7055	12%
2001	3613	337	2913	815	0	7677	15%
2002	2476	248	2642	493	0	5859	13%
2003	3236	373	2107	809	0	6525	18%
2004	5837	549	96	422	0	6905	14%
2005	3161	476	30	255	0	3922	19%
2006	1196	377	25	565	0	2162	44%

Table C.2 Georges Bank US landings (metric tons) and number of lengths available from port samples by half year and market category along with number of ages available for age-length key and number of lengths sampled per 100 metric tons.

		Landings (metric tons)					Number of Lengths					Number	Lengths /
Year	half	unclass	large	small	medium	Total	unclass	large	small	medium	Total	of Ages	100 mt
1994	1	5	109	58		172							
	2	1	664	593		1258		517	724		1241		
	Total	7	773	650		1431		517	724		1241	302	87
1995	1	1	114	76		191		411	475		886		
	2	2	80	87		169		92	131		223		
	Total	3	195	162		360		503	606		1109	284	308
1996	1	1	382	161		544		254	250		504		
	2	2	102	95	0	199		192	268		460		
	Total	3	485	256	0	743		446	518		964	260	130
1997	1	10	428	169	0	607		628	1072		1700		
	2	3	179	99		281		91	121		212		
	Total	14	607	268	0	888		719	1193		1912	508	215
1998	1	43	383	141		567		555	490		1045		
	2	26	448	577		1052		199	85		284		
	Total	69	832	718		1619		754	575		1329	293	82
1999	1	39	679	296		1014		435	451		886		
	2	25	536	243	0	804		137	125		262		
	Total	63	1215	539	0	1818		572	576		1148	213	63
2000	1	55	1454	520	0	2029	114	526	260		900		
	2	38	885	420		1344	300	543	595		1438		
	Total	94	2339	941	0	3373	414	1069	855		2338	529	69
2001	1	98	1887	585		2570		1015	592		1607		
	2	31	777	235		1043		459	958		1417		
	Total	128	2664	820		3613		1474	1550		3024	702	84
2002	1	45	1679	356	0	2080		780	357		1137		
	2	10	271	115	0	396		680	327		1007		
	Total	55	1950	471	0	2476		1460	684		2144	543	87
2003	1	31	1586	457		2074		1276	994		2270		
	2	7	897	258		1162		1244	1028		2272		
	Total	37	2483	715		3236		2520	2022		4542	1144	140
2004	1	52	2477	439	4	2972		3249	2314		5563		
	2	29	2132	684	20	2865		1565	1362		2927		
	Total	81	4609	1123	24	5837		4814	3676		8490	1699	145
2005	1	17	851	497	9	1374		2351	1282		3633		
	2	21	1114	639	12	1787	93	2636	1686		4415		
	Total	38	1965	1136	22	3161	93	4987	2968		8048	1798	255
2006	1	24	580	170	7	781	128	3183	2447		5758		
	2	6	248	155	7	415		2147	1600		3747		
	Total	29	827	325	14	1196	128	5330	4047		9505	2248	795
Grand Total		622	20944	8125	60	29751	635	25165	19994		45794	10523	154

Table C.3 Georges Bank yellowtail flounder coefficient of variation for US landings at age by year.

Year	age 1	age 2	age 3	age 4	age 5	age 6+
1994		57%	6%	14%	27%	41%
1995		27%	11%	13%	22%	40%
1996		23%	7%	15%	26%	60%
1997		17%	11%	8%	30%	35%
1998		64%	31%	16%	36%	30%
1999	97%	21%	9%	25%	33%	34%
2000		11%	9%	11%	20%	32%
2001		17%	11%	10%	22%	48%
2002	76%	15%	11%	11%	15%	22%
2003		16%	8%	9%	11%	16%
2004		53%	8%	6%	9%	11%
2005		11%	4%	6%	12%	16%
2006		10%	5%	6%	6%	13%

Table C.4 Georges Bank yellowtail flounder US discards (metric tons) and coefficient of variation by gear and year.

	Otter Trawl Large Mesh		Otter Trawl Small Mesh		Scallop Dredge	
Year	D (mt)	CV	D (mt)	CV	D (mt)	CV
1994	138	150%	0	0%	10	6%
1995	36	70%	0	0%	7	20%
1996	51	30%	0	0%	45	0%
1997	211	22%	0	0%	117	74%
1998	185	66%	0	0%	297	46%
1999	11	67%	0	0%	566	13%
2000	25	71%	0	90%	669	12%
2001	50	51%	0	105%	28	7%
2002	24	42%	0	79%	29	27%
2003	115	39%	1	95%	293	0%
2004	324	20%	55	62%	81	21%
2005	177	12%	52	28%	186	20%
2006	107	14%	26	95%	251	19%

Table C.5 Georges Bank yellowtail flounder catch at age (thousands of fish).

Year	age1	age2	age3	age4	age5	age6+
1973	359	5175	13565	9473	3815	1650
1974	2368	9500	8294	7658	3643	1520
1975	4636	26394	7375	3540	2175	1207
1976	635	31938	5502	1426	574	918
1977	378	9094	10567	1846	419	495
1978	9962	3542	4580	1914	540	211
1979	321	10517	3789	1432	623	325
1980	318	3994	9685	1538	352	113
1981	107	1097	5963	4920	854	145
1982	2164	18091	7480	3401	1095	96
1983	703	7998	16661	2476	680	155
1984	514	2018	4535	5043	1796	379
1985	970	4374	1058	818	517	81
1986	179	6402	1127	389	204	113
1987	156	3284	3137	983	192	137
1988	499	3003	1544	846	227	53
1989	190	2175	1121	428	110	30
1990	231	2114	6996	978	140	26
1991	663	147	1491	3011	383	71
1992	2414	9167	2971	1473	603	42
1993	5233	1386	3327	2326	411	91
1994	71	1336	6302	1819	477	144
1995	47	313	1435	879	170	37
1996	101	681	2064	885	201	28
1997	82	1132	1832	1857	378	90
1998	169	1991	3388	1885	1121	146
1999	60	2753	4195	1548	794	301
2000	132	3864	5714	3173	826	528
2001	176	2884	6956	2893	1004	525
2002	212	4169	3446	1916	683	485
2003	160	3919	4710	2320	782	693
2004	64	1201	3171	3804	1970	1451
2005	60	1529	4086	1712	411	178
2006	154	1300	1698	1003	373	214

Table C.6 Georges Bank yellowtail flounder catch weight at age (kg).

Year	age1	age2	age3	age4	age5	age6+
1973	0.101	0.348	0.462	0.527	0.603	0.778
1974	0.115	0.344	0.496	0.607	0.678	0.832
1975	0.113	0.316	0.489	0.554	0.619	0.695
1976	0.108	0.312	0.544	0.635	0.744	0.861
1977	0.116	0.342	0.524	0.633	0.780	0.931
1978	0.102	0.314	0.510	0.690	0.803	0.970
1979	0.114	0.329	0.462	0.656	0.736	0.950
1980	0.101	0.322	0.493	0.656	0.816	1.072
1981	0.122	0.335	0.489	0.604	0.707	0.840
1982	0.115	0.301	0.485	0.650	0.754	1.082
1983	0.140	0.296	0.441	0.607	0.740	1.010
1984	0.162	0.239	0.379	0.500	0.647	0.797
1985	0.181	0.361	0.505	0.642	0.729	0.800
1986	0.181	0.341	0.540	0.674	0.854	1.015
1987	0.121	0.324	0.524	0.680	0.784	0.875
1988	0.103	0.328	0.557	0.696	0.844	0.975
1989	0.100	0.327	0.520	0.720	0.866	1.053
1990	0.105	0.290	0.395	0.585	0.693	0.845
1991	0.121	0.237	0.369	0.486	0.723	0.877
1992	0.101	0.293	0.365	0.526	0.651	1.110
1993	0.100	0.285	0.379	0.501	0.564	0.863
1994	0.193	0.260	0.353	0.472	0.621	0.775
1995	0.174	0.275	0.347	0.465	0.607	0.768
1996	0.119	0.276	0.407	0.552	0.707	1.012
1997	0.214	0.302	0.408	0.538	0.718	0.947
1998	0.178	0.305	0.428	0.546	0.649	0.966
1999	0.202	0.368	0.495	0.640	0.755	0.901
2000	0.229	0.383	0.480	0.615	0.766	0.954
2001	0.251	0.362	0.460	0.612	0.812	1.027
2002	0.282	0.381	0.480	0.665	0.833	1.068
2003	0.228	0.359	0.474	0.653	0.824	1.048
2004	0.211	0.296	0.440	0.586	0.728	0.956
2005	0.119	0.341	0.445	0.594	0.767	0.997
2006	0.100	0.309	0.411	0.555	0.760	0.998

Table C.7a NEFSC Spring survey indices of abundance for Georges Bank yellowtail flounder.

Year	age1	age2	age3	age4	age5	age6+	kg/tow
1973	1.940	3.281	2.379	1.068	0.412	0.217	2.939
1974	0.318	2.234	1.850	1.262	0.347	0.282	2.720
1975	0.422	3.006	0.834	0.271	0.208	0.089	1.676
1976	1.039	4.388	1.253	0.312	0.197	0.112	2.273
1977	0.000	0.674	1.131	0.375	0.084	0.013	0.999
1978	0.940	0.802	0.509	0.220	0.027	0.008	0.742
1979	0.406	2.016	0.407	0.338	0.061	0.091	1.271
1980	0.057	4.666	5.787	0.475	0.057	0.036	4.456
1981	0.012	1.026	1.776	0.720	0.213	0.059	1.960
1982	0.045	3.767	1.130	1.023	0.458	0.091	2.500
1983	0.000	1.865	2.728	0.530	0.123	0.245	2.642
1984	0.000	0.093	0.830	0.863	0.835	0.244	1.646
1985	0.110	2.199	0.262	0.282	0.148	0.000	0.988
1986	0.027	1.806	0.291	0.056	0.137	0.055	0.847
1987	0.027	0.076	0.137	0.133	0.053	0.055	0.329
1988	0.078	0.275	0.366	0.242	0.199	0.027	0.566
1989	0.047	0.403	0.760	0.290	0.061	0.045	0.729
1990	0.000	0.066	1.107	0.369	0.116	0.104	0.699
1991	0.435	0.000	0.254	0.685	0.263	0.021	0.631
1992	0.000	2.048	1.896	0.641	0.165	0.017	1.566
1993	0.046	0.290	0.501	0.317	0.027	0.000	0.482
1994	0.000	0.621	0.633	0.354	0.145	0.040	0.661
1995	0.040	1.179	4.812	1.485	0.640	0.010	2.579
1996	0.025	0.987	2.626	2.701	0.610	0.058	2.853
1997	0.019	1.169	3.733	4.081	0.703	0.134	4.359
1998	0.000	2.081	1.053	1.157	0.759	0.350	2.324
1999	0.050	4.746	10.820	2.720	1.623	0.779	9.307
2000	0.183	4.819	7.666	2.914	0.813	0.524	6.696
2001	0.000	2.315	6.563	2.411	0.483	0.453	5.006
2002	0.188	2.412	12.333	4.078	1.742	0.871	9.563
2003	0.202	4.370	6.764	2.876	0.442	0.862	6.722
2004	0.049	0.986	2.178	0.680	0.255	0.272	1.891
2005	0.000	2.013	5.080	2.403	0.270	0.115	3.407
2006	0.508	0.935	3.523	2.177	0.317	0.082	2.420
2007	0.090	5.048	6.263	2.846	0.556	0.129	4.701

Table C.7b NEFSC Fall survey indices of abundance for Georges Bank yellowtail flounder.

Year	age1	age2	age3	age4	age5	age6+	kg/tow
1973.5	2.494	5.498	5.104	2.944	1.217	0.618	6.490
1974.5	4.623	2.864	1.516	1.060	0.458	0.379	3.669
1975.5	4.686	2.511	0.878	0.572	0.334	0.063	2.326
1976.5	0.344	1.920	0.474	0.117	0.122	0.100	1.508
1977.5	0.934	2.212	1.620	0.634	0.105	0.109	2.781
1978.5	4.760	1.281	0.780	0.411	0.136	0.036	2.343
1979.5	1.321	2.069	0.261	0.120	0.138	0.112	1.494
1980.5	0.766	5.120	6.091	0.682	0.219	0.259	6.607
1981.5	1.595	2.348	1.641	0.588	0.079	0.054	2.576
1982.5	2.425	2.185	1.590	0.423	0.089	0.000	2.270
1983.5	0.109	2.284	1.915	0.511	0.031	0.049	2.131
1984.5	0.661	0.400	0.306	0.243	0.075	0.063	0.593
1985.5	1.350	0.544	0.171	0.051	0.081	0.000	0.709
1986.5	0.282	1.108	0.349	0.074	0.000	0.000	0.820
1987.5	0.102	0.401	0.396	0.053	0.079	0.000	0.509
1988.5	0.019	0.213	0.107	0.027	0.000	0.000	0.171
1989.5	0.248	1.993	0.773	0.079	0.056	0.000	0.977
1990.5	0.000	0.370	1.473	0.295	0.000	0.000	0.725
1991.5	2.101	0.275	0.439	0.358	0.000	0.000	0.730
1992.5	0.151	0.396	0.712	0.162	0.144	0.027	0.576
1993.5	0.839	0.139	0.586	0.536	0.000	0.022	0.546
1994.5	1.195	0.221	0.983	0.713	0.263	0.057	0.897
1995.5	0.276	0.119	0.345	0.275	0.046	0.013	0.354
1996.5	0.149	0.352	1.869	0.447	0.075	0.000	1.303
1997.5	1.393	0.533	3.442	2.090	1.071	0.082	3.781
1998.5	1.900	4.817	4.202	1.190	0.298	0.074	4.347
1999.5	3.090	8.423	5.727	1.432	1.436	0.260	7.973
2000.5	0.629	1.697	4.814	2.421	0.948	0.827	5.838
2001.5	3.518	6.268	8.091	2.601	1.718	2.048	11.553
2002.5	2.093	5.751	2.127	0.594	0.305	0.027	3.754
2003.5	1.077	5.031	2.808	0.565	0.100	0.191	4.038
2004.5	0.876	5.508	5.010	2.106	0.924	0.176	5.117
2005.5	0.313	2.095	3.763	0.614	0.185	0.000	2.463
2006.5	6.194	6.251	3.664	1.167	0.255	0.046	4.521
2007.5	1.058	11.447	7.866	1.998	0.383	0.094	8.151

Table C.7c DFO Winter survey indices of abundance for Georges Bank yellowtail flounder.

Year	age1	age2	age3	age4	age5	age6+
1987	0.120	0.988	2.002	0.638	0.121	0.044
1988	0.000	1.588	1.292	0.760	0.295	0.027
1989	0.114	0.941	0.583	0.364	0.088	0.044
1990	0.000	2.359	3.383	1.064	0.322	0.024
1991	0.024	0.858	1.531	3.230	0.725	0.000
1992	0.055	10.745	3.969	1.034	0.301	0.037
1993	0.079	2.245	3.265	4.406	1.635	0.058
1994	0.000	6.056	3.464	3.006	0.781	0.207
1995	0.210	1.190	4.281	2.554	0.785	0.087
1996	0.446	6.655	8.579	6.615	1.010	0.142
1997	0.022	9.781	14.674	17.957	4.324	0.732
1998	0.893	3.179	4.891	4.504	2.021	0.524
1999	0.159	11.841	27.242	7.949	7.296	2.587
2000	0.011	9.468	32.902	17.802	5.539	3.497
2001	0.291	15.176	47.131	13.353	3.696	2.950
2002	0.088	9.667	33.733	11.269	5.970	2.958
2003	0.066	6.759	27.355	13.450	3.570	1.890
2004	0.033	3.599	16.260	9.205	2.273	1.416
2005	0.600	1.602	27.959	20.564	5.696	1.565
2006	0.623	4.893	18.600	6.572	0.820	0.238
2007	0.173	12.159	27.708	12.799	2.288	0.248

Table C.7d NEFSC Scallop survey index of abundance for Georges Bank yellowtail flounder.

Year	age 1	Year	age 1
1982.5	0.313	1995.5	0.609
1983.5	0.140	1996.5	0.508
1984.5	0.233	1997.5	1.062
1985.5	0.549	1998.5	1.872
1986.5	0.103	1999.5	1.038
1987.5	0.047	2000.5	0.912
1988.5	0.116	2001.5	0.789
1989.5	0.195	2002.5	1.005
1990.5	0.100	2003.5	0.880
1991.5	2.117	2004.5	0.330
1992.5	0.167	2005.5	0.573
1993.5	1.129	2006.5	2.422
1994.5	1.503		

Table C.8 Parametric estimates of biological reference points for Georges Bank yellowtail flounder for the Base Case and Major Change models under three priors for unfished recruitment (millions of fish). Fmsy is fully recruited F (ages 4-6), while SSBmsy and MSY are in thousand metric tons.

Model	R prior	Fmsy	SSBmsy	MSY
Base Case	none	0.395	39.7	12.9
	70	0.360	62.8	18.8
	89	0.345	82.2	23.7
Major Change	none	0.425	31.1	10.7
	64	0.365	58.0	17.5
	80	0.350	74.5	21.6

Table C.9 Empirical estimates of biological reference points for Georges Bank yellowtail flounder for the Base Case and Major Change models under three time series of recruitment (millions of fish).

Model	R range	Fmsy	SSBmsy	MSY
Base Case	1973-2006	0.252	27.2	5.9
	top 14	0.252	90.0	19.5
	top 10	0.252	108.0	23.4
Major Change	1973-2006	0.254	26.0	5.6
	top 14	0.254	80.6	17.5
	top 10	0.254	95.3	20.7

Table C.10 Combination approach to setting reference points for the Major Change model only using the Beverton and Holt stock recruitment relationship but assuming Fmsy is derived from F40%SPR under three priors for unfished recruitment.

Model	R prior	Fmsy	SSBmsy	MSY
Major Change	none	0.254	46.8	10.2
	64	0.254	78.0	16.9
	80	0.254	97.0	21.0

Figure C.1 Total catch of Georges Bank yellowtail flounder.

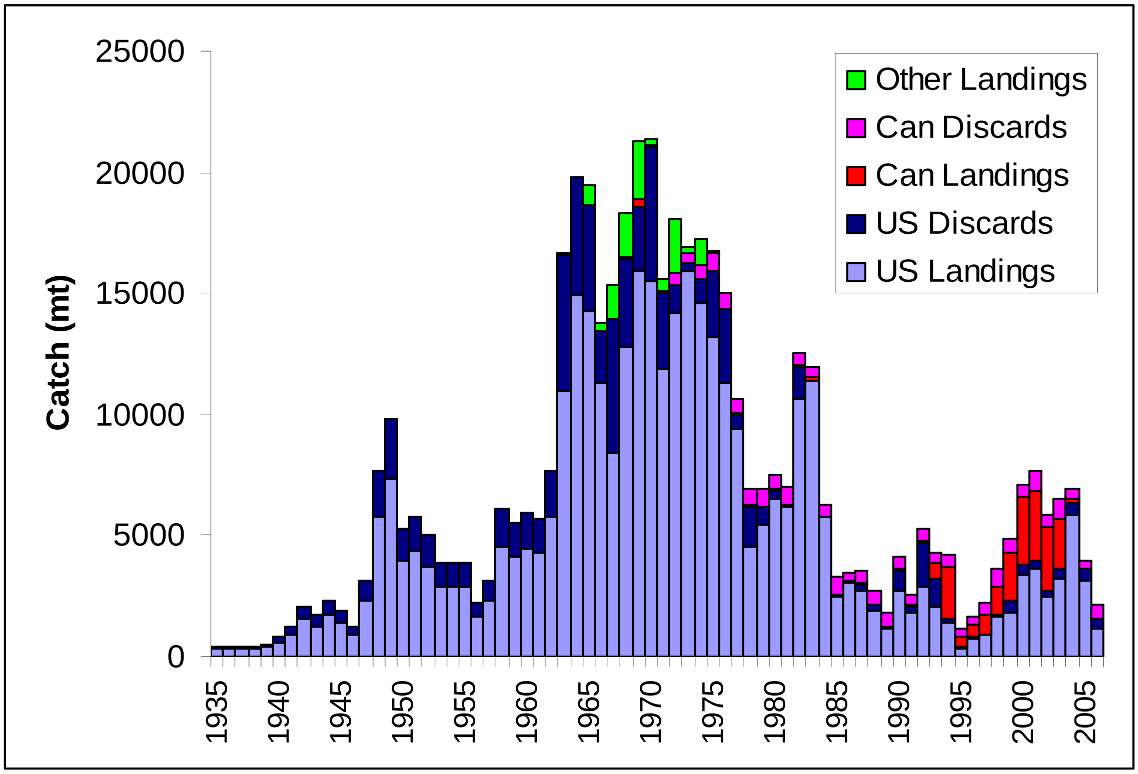


Figure C.2 Trends in survey biomass for Georges Bank yellowtail flounder.

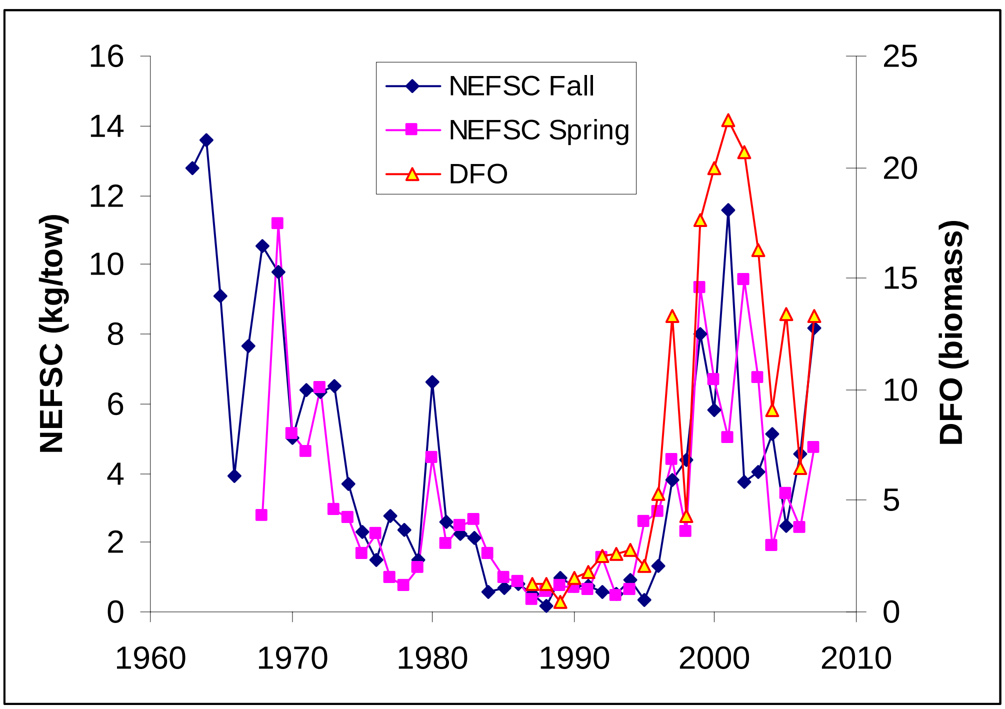
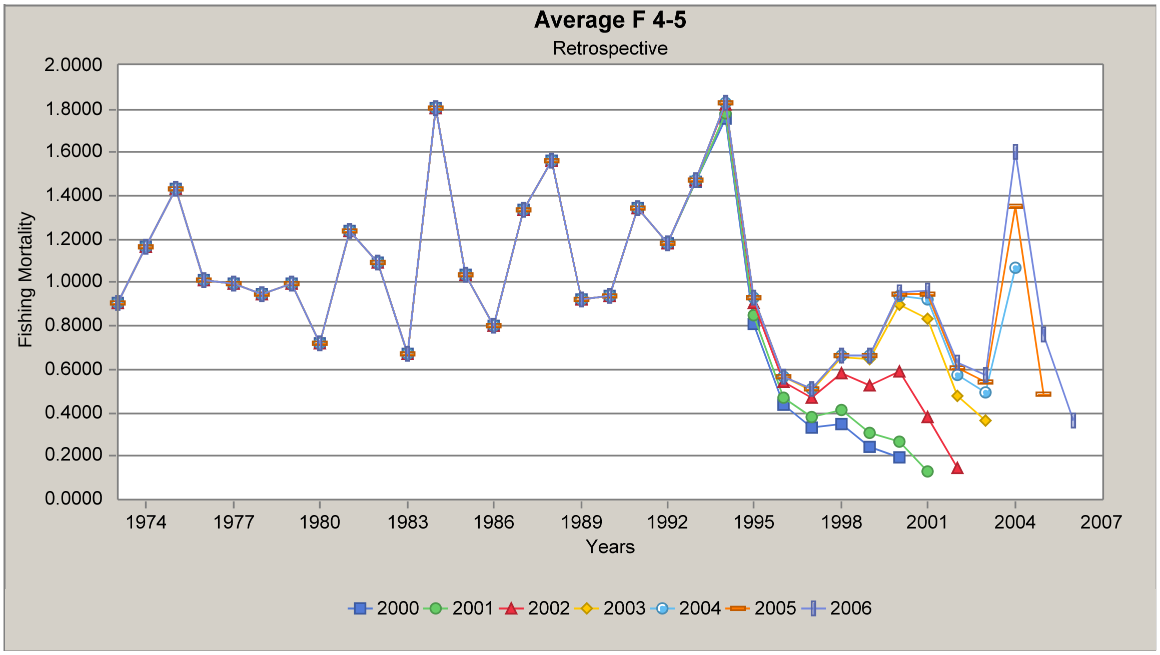


Figure C.3 Retrospective plots of fully recruited fishing mortality rate (ages 4-5) and spawning stock biomass from the Base Case VPA.



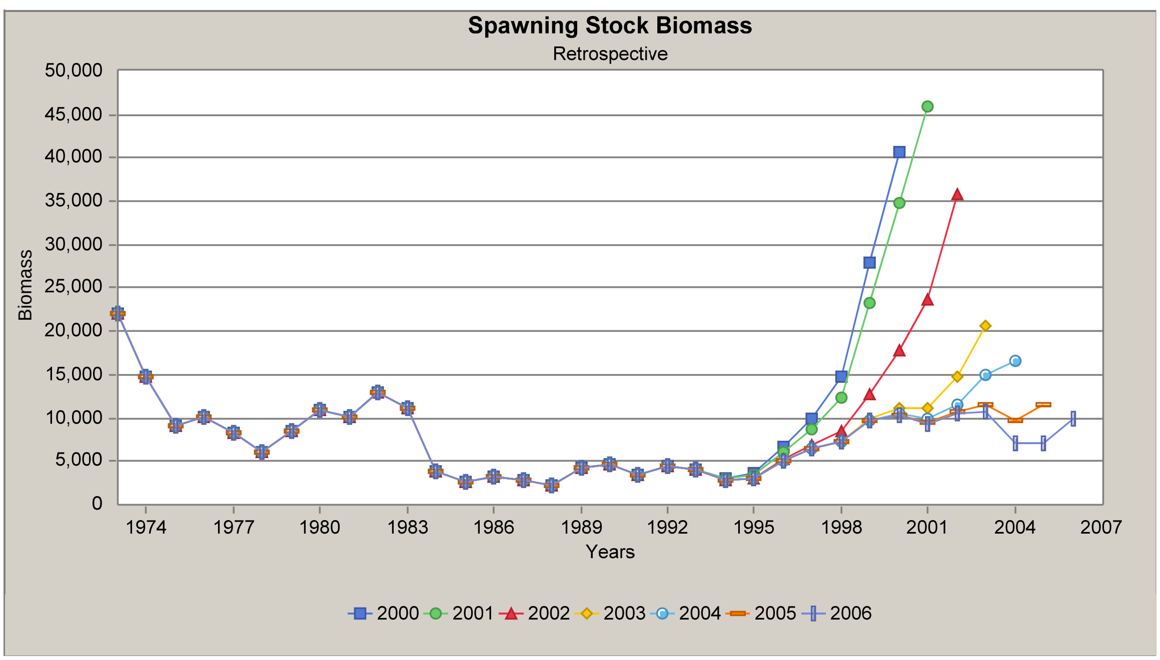
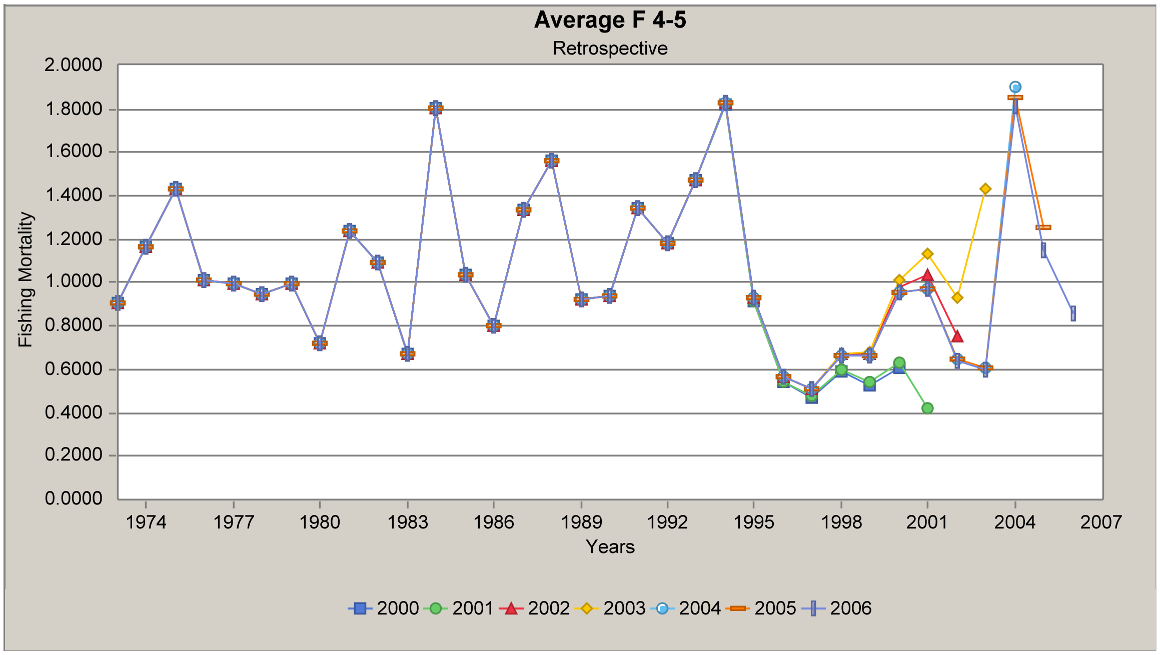


Figure C.4 Retrospective plots of fully recruited fishing mortality rate (ages 4-5) and spawning stock biomass from the Major Change VPA.



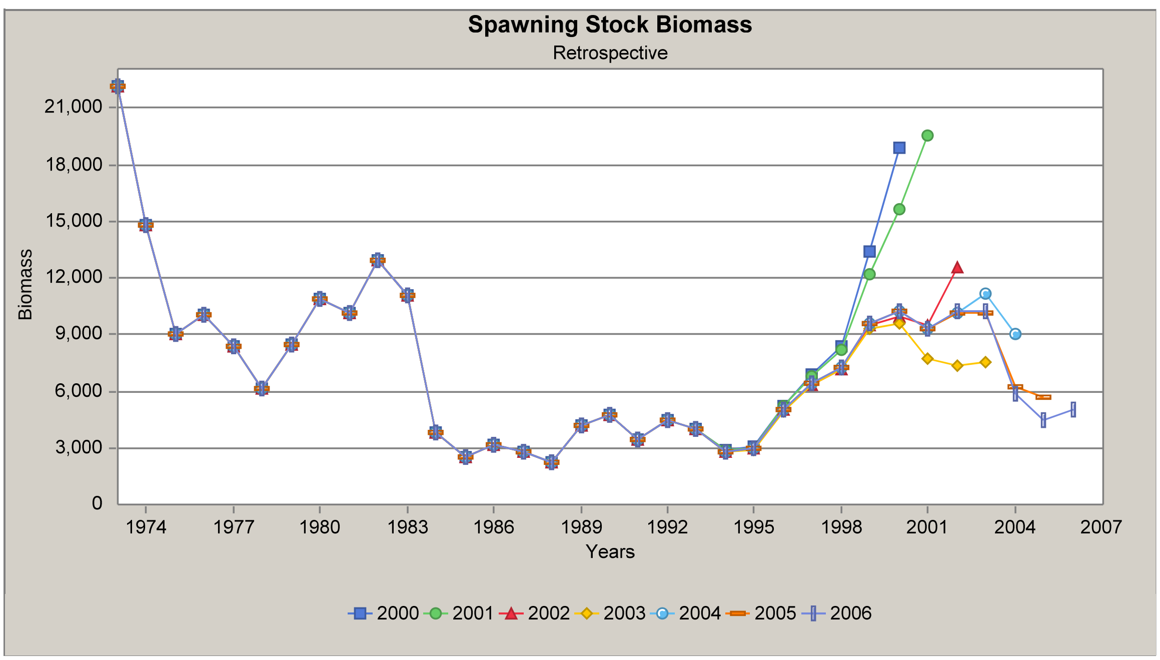


Figure C.5 Stock recruitment relationships for the Base Case and Major Change models.

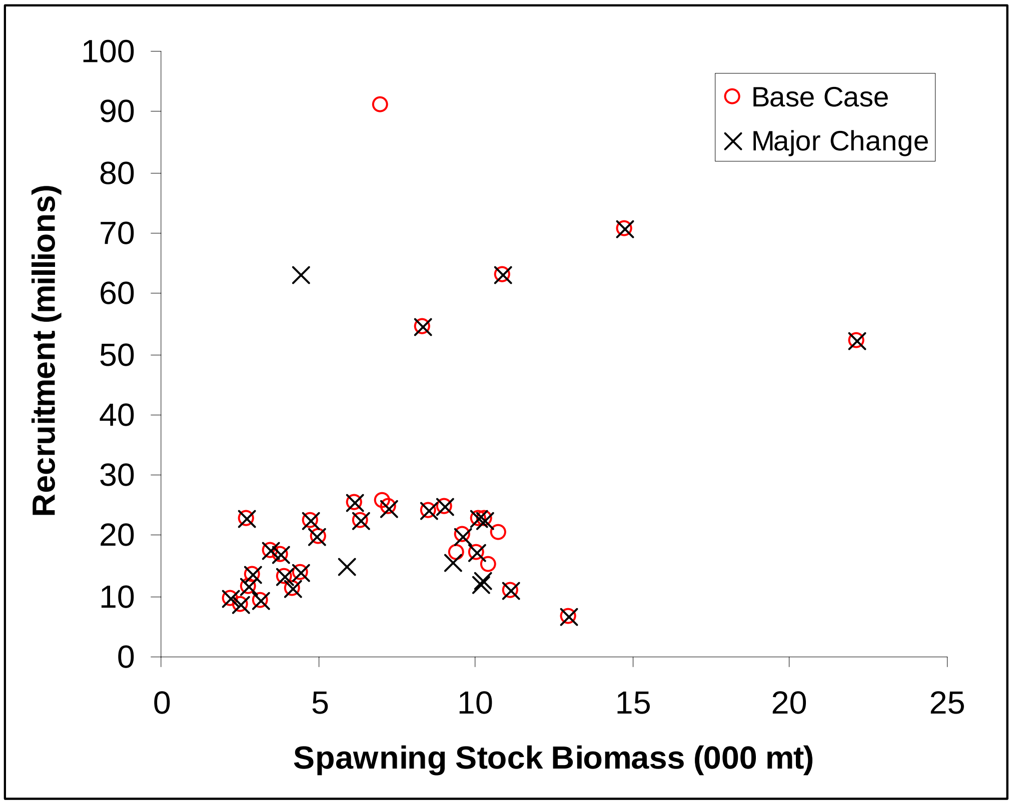
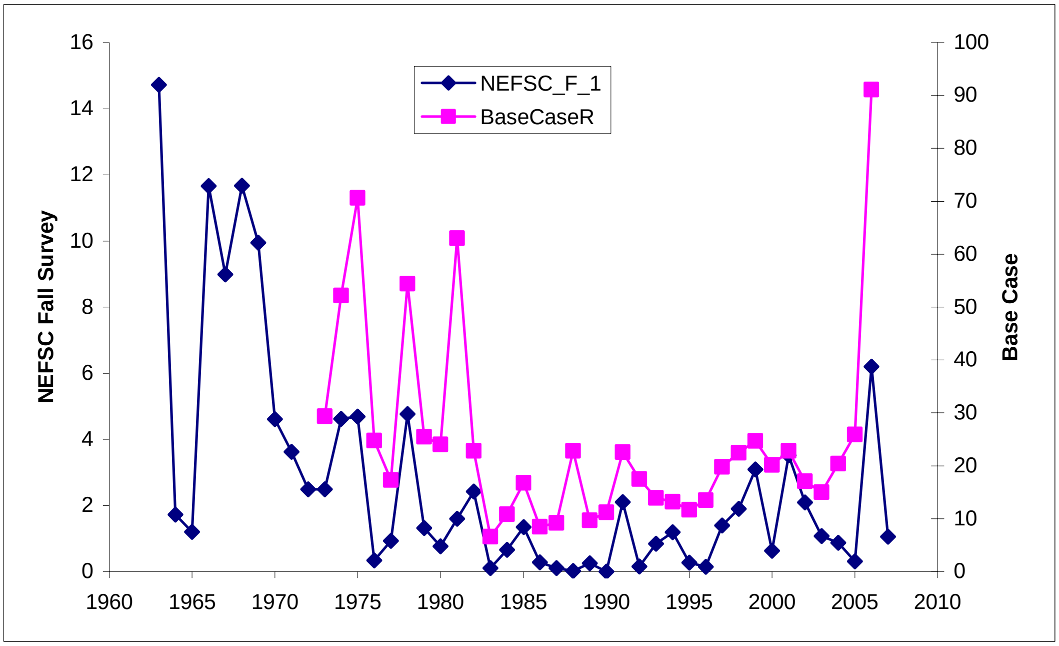


Figure C.6 Hindcast estimates of recruitment using the NEFSC Fall survey at age 1 and the Base Case model.



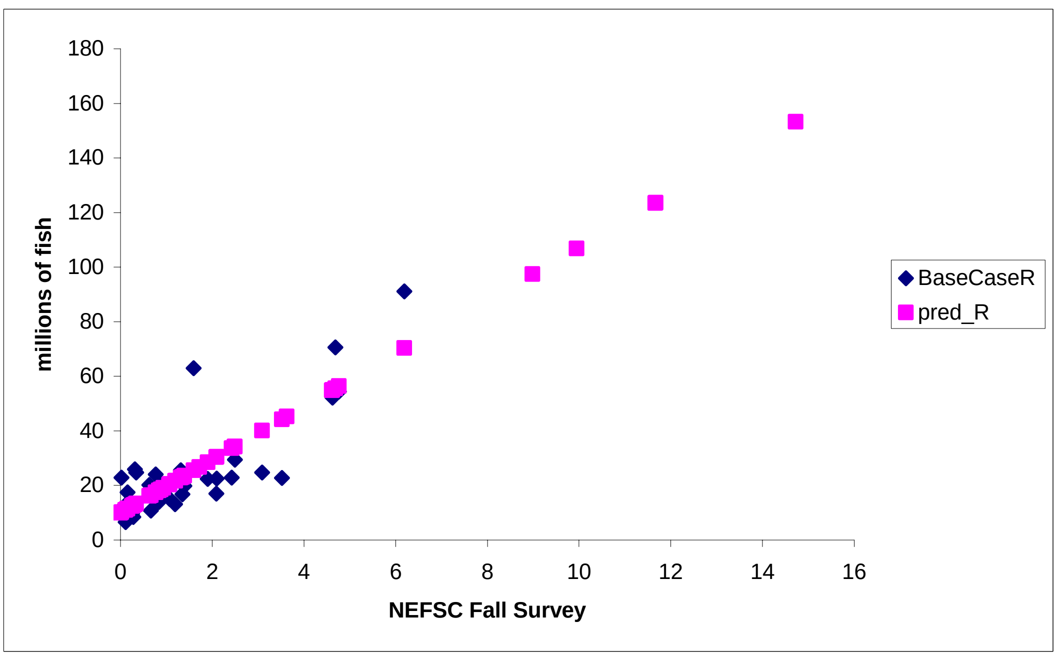
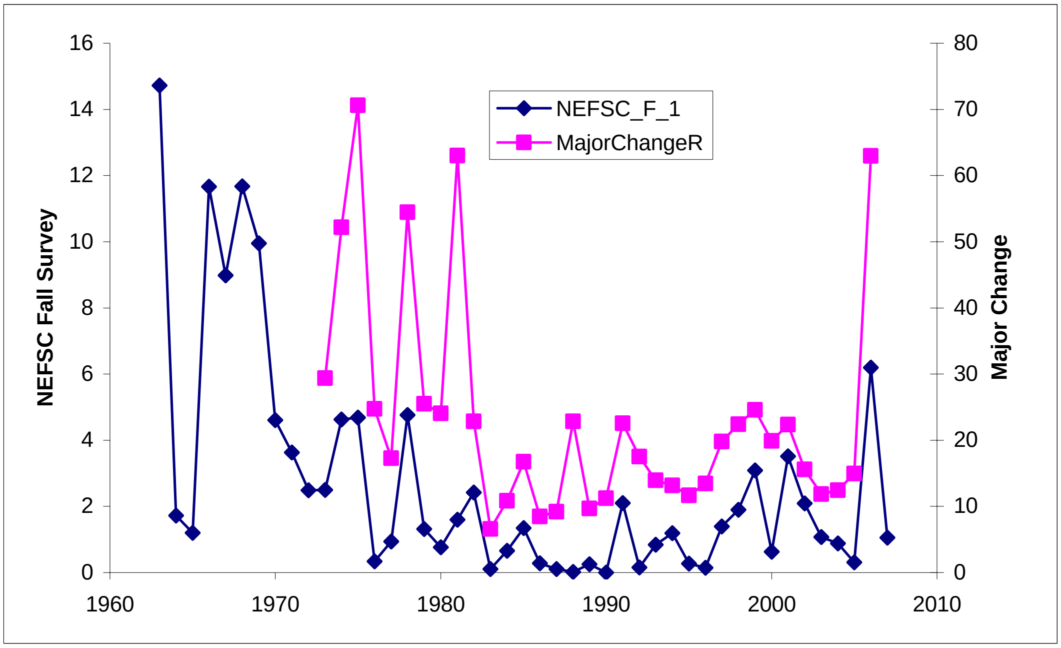


Figure C.7 Hindcast estimates of recruitment using the NEFSC Fall survey at age 1 and the Major Change model.



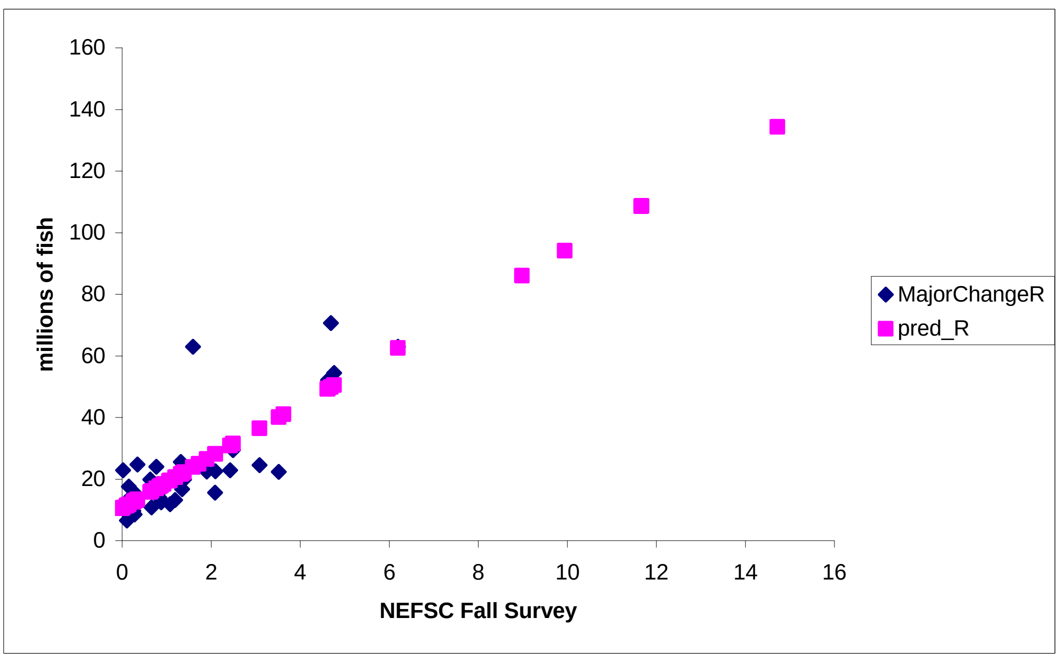


Figure C.8 Current status of Georges Bank yellowtail flounder based on two stock assessment models (Base Case and Major Change), parametric (P) or empirical (E) approach to estimating biological reference points, and three levels of recruitment (same symbols, largest recruitment in set of three associated with point farthest to the left).